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THE HACKBERRY PSYLLA, PACHYPSYLLA CELTIDIS-MAMMÆ RILEY.
A STUDY IN COMPARATIVE INSECT MORPHOLOGY, . . *H. B. Stough.*

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THE HACKBERRY PSYLLA, PACHYPSYLLA CELTIDIS-MAMMÆ RILEY.

A STUDY IN COMPARATIVE MORPHOLOGY.

BY H. B. STOUGH.

Plates XXVI to XXXV, and three figures.

(Contribution from Entomological Laboratory, No. 158.)

Submitted in partial fulfillment of the requirements for the degree of Master of Arts.

OWING to their minute size and obscure life habits, the members of the homopterous family Psyllidæ have received comparatively little attention in North America. In the present paper an endeavor will be made to add to our knowledge of this family, using as a type *Pachypsylla celtidis-mammæ* Riley, the same being a study in comparative morphology of mouth parts, thorax, and genitalia, and development of wing venation and wing pattern. The specimens upon which I have based my studies emerged from their galls upon the hackberry trees during October of 1908, at Lawrence, Kan. I wish to thank Prof. S. J. Hunter, upon whose suggestion the problem was taken up, and under whose guidance and counsel the work was carried on, for his interest in my investigations and for his assistance rendered.

In search for literature on the Psyllidæ of North America, and especially that dealing with *Pachypsylla celtidis-mammæ* and its genus, I was impressed with the fact that very little of a definite and final treatment has ever been given to these insects in this country. A few species have been described, a few figured, and the life histories of a number worked out, while keys for the species of only about one genus can be found.

In Europe, on the contrary, the contributions to the knowl-

edge of this family have been numerous and have added greatly to our information on the subject. The first of these contributions was made by Förster, in 1848. He was followed by Flör, Thomson, and Hartig, but not much of an advance was made upon Förster's work until there appeared in 1879 a treatise, "Zur Systematik der Psylliden," by Löw; this, together with other contributions by the same author, has long remained authoritative. The researches of Löw in the taxonomy and biology of the Psyllidæ, together with the anatomical work of Witlaczil, have much simplified the study of this family in Europe.

James Edwards, in "Hemiptera-Homoptera" (1896), treats of four genera of the family, including twenty-eight species of British Psyllidæ, with tables for the separation of the genera and species. He also illustrates these forms in color and gives the typical wing venation of each genus.

Maskel (1889) lists and describes four species of Psyllidæ from New Zealand, giving keys for separating the subfamilies represented in that locality, and figures the larval, pupal and adult stages, and some of their typical anatomical characters. This paper contains more figures of these characters than any other I have been able to find, and was quite useful from that standpoint. This writer also discusses the use and taxonomic importance of the different characters of the family.

Froggatt (1903), in a paper on "Australian Psyllidæ" describes eighteen species, mostly of the two genera *Aphalaria* and *Trioza*. He figures the galls made by three species of the latter genus.

The reasons for the dearth of material in this country may be found in the fact that the family Psyllidæ, like some other little-known groups, being composed of small and inconspicuous insects, has not been largely collected and studied, two or three species excepted. One of these, the pear Psylla, *Psylla pyricola*, is of great economic importance in some localities, and has long been known and its life history carefully worked out. The life histories of these insects are very difficult to determine definitely, and since some of them are gall-formers, the biological side of the work becomes still more complicated. Only about three specialists have ever devoted much time to their study in this country, among whom was C. V. Riley. In an article on "The Psyllidæ of the United States" (1883), he gives a *résumé* of the present knowledge of the family and its principal char-

acters, habits, life history, etc., listing thirteen species. Undoubtedly the most important work published so far is that by the same writer entitled "Notes on North American Psyllidæ" (1884). This paper lists nineteen North American species, distributed among the following genera: *Livia, Aphalara, Psylla, Pachypsylla, Trioza, Calophyla, Rhinopsylla,* and *Ceratopsylla,* the descriptions of three genera and two species being new. The most important part of this work, from the standpoint of the present paper, is that dealing with the new genus *Pachypsylla.* This genus is peculiar to this continent, having no equivalent in Europe, so Riley thinks, and to it belong the hackberry psyllids. Only three species of these are placed in his key. Riley also discusses "hackberry galls," in the *Canadian Entomologist* (1883).

An important contribution to the biology of the subject, especially of the gall-making phase, is an article on psyllid gall-making in the fifth report of the United States Entomological Commission, written by A. S. Packard (1887). This gives keys to three species; descriptions of pupa; key to, and descriptions of, the galls of the following species and varieties of the genus *Pachypsylla: venusta, gemma, asteriscus, umbilicus, mamma, pubescens, globulus, cucurbita,* and *cucurbita var.* To this is added a detailed description of each gall and a condensed general life history of a hackberry psyllid. No mention is made of the stimuli causing the gall-formation. Ashmead (1881) describes the life histories and gall-making habits of these insects, and lists nine species, adding three new ones.

Two papers by Charles W. Mally, entitled, respectively, "Hackberry Psyllidæ Found at Ames, Iowa" (1893), and "Psyllidæ Found at Ames" (1894), give a series of observations on the winter habits and spring egg-laying of *Pachypsylla celtidis-mammæ,* with descriptions of the eggs, larvæ, pupæ, and galls, and record thirty-one species for North America. He describes four new species and figures the early stages and wing venations.

Where mention is made of the galls in the papers that I have mentioned, only the gross structure of the gall is treated. Cook, however, in "Galls and Insects Producing Them" (1903-'04), has made a contribution toward the histology of the psyllid gall; he also discusses mouth parts and ovipositors in their relation to gall-formation, but in common with other investiga-

tors was not able to add much to our knowledge of the gall-producing stimuli.

On the mouth parts of Hemiptera, in addition to works of a general nature, I would cite two of importance in throwing light upon the homopterous mouth as seen in the Psyllidæ. These are by Charles L. Marlatt (1898) and Walter J. Meek (1903), and deal with the mouth parts of the cicada. Besides these, such works as those of Sanborn on the Aphididæ (1905), Berlese on Coccidæ (1896), and others, were of use in a comparative study. The best work upon mouth parts of Hemiptera is recorded in the German of Leon (1887), Geise (1883), Wedde (1885), and Heymonds (1899). Dohrn (1865) contributed to the internal anatomy of the Hemiptera, and Witlaczil (1885) worked out the brain, eyes and digestive system.

GENERAL CHARACTERS OF THE FAMILY PSYLLIDÆ.

The Psyllidæ were formerly classified with the Aphididæ, to which they are closely related, and are still sometimes known as "the jumping plant lice." These insects are from one-eighth to one-fifth of an inch long and in general appearance may be likened to a minute cicada. Their principal characters follow: Hind legs developed for jumping; antennæ nine- or ten-segmented (in life in constant vibration), last segment bearing two short spines; tarsi two-segmented; mouth parts suctorial; wing venation comparatively simple. Some of the species are of economic interest, being injurious through their feeding habits. A number form galls, notably upon hackberry. A few species secrete "honey dew."

According to Mally (1894) there are thirty-nine species and varieties in North America. Only nine species are to be found in the collection of the University of Kansas, four of these having been taken in Kansas. So far, not many fossil insects of this family are known. Scudder lists in "Tertiary Insects of America" (1890) only two species, *Necropsylla rigida* and *Catopsylla prima*, the latter being of interest, as its wing venation resembles more closely that of Riley's genus *Pachypsylla* than of any other.

The species taken for study belongs to this last genus, *Pachypsylla*. The namer, C. V. Riley, says of it: "There is no genus among those characterized by Dr. Fr. Löw with which

Pachypsylla can properly be compared. In the convexity of the body it greatly surpasses *Psylla*, from which it is at once distinguished by the vertical and rugosepunctate head, the quadrate vertex, the short frontal cones, the less filiform and stout antennæ." This species was first listed for Kansas by Tucker in 1907.

The coloration of *Pachypsylla* has been well described by Riley. The general color is dark brown, with the abdomen showing pinkish shades along the edges of each segment. The wing pattern is dark brown, and the ocelli are red.

This insect is quite short bodied; the sexes are easily distinguished, as in all representatives of the family, the end of the abdomen being pointed in the female but blunt and appendage-bearing in the male. The total length of body averages, for the male, 3.2 mm., and for the female, 3.6 mm.

HEAD.

The head is carried in such a position relative to the remainder of the body that the epicranium is in an almost vertical position (*34*-4),* the frontal cones pointing downward, with the outer face of the frons in a horizontal position, its distal end projecting caudad. Viewed from the front, the head corresponds roughly, in general shape, to a right triangle, truncate at the vertex, the posterior edge of the epicranium lying on the base of this triangle, and a point somewhat beyond the frontal cones representing the vertex (*28*-4). The whole head is rather flat, thin, rectangular, and boxlike, the open side of the box being the caudal side (*28*-1), against and into which opening fit the anterior part of the prosternum, the procoxæ and the mouth parts.

The following parts and regions of the head, excluding the frons and clypeus, which will be described under "mouth parts," are to be found: epicranium, genæ, frontal cones, antennal sockets, compound eyes, and ocelli.

The epicranium forms the front wall of the head and is vertical in position. Its posterior margin is slightly concave, and curves caudad and ventrad to the opposite side of the head, forming a roll-like edge. This roll-like portion is the dorsal part of the head when the latter is in normal position. This region of the head (*28*-4, *ep*) is rectangular, about 0.45 mm.

* Read plate XXXIV, fig. 4.

wide and 0.62 mm. long. Its posterior edge is concave, as are also the lateral edges which border on the compound eyes, while the anterior margin is quite convex and has a somewhat more than semicircular excision at its median point, in which region is located the frontal ocellus, seen in figures 4 and 5, *fo*, and in 2 in longitudinal section, pl. 28. The epicranium is seen to be flat in surface when the head is viewed in profile. The other two ocelli (*28*-4, *o*) are placed at the two posterior angles of the epicranium, near its margin and slightly posterior to the compound eyes. They are about 0.07 mm. in diameter. The epicranium is divided along its median line by a very plainly cut suture into two equal sclerites. This suture is deep, and in making dissections of the head these two sclerites were often separated readily along this line. The anterior, convex suture between the epicranium and the rest of the head was not so apparent in most specimens that I examined, though usually those boiled thoroughly in potassium hydrate and then carefully cleared in xylol showed it more plainly. The surface of the epicranium is rugose-punctate, slightly pubescent.

The frontal cones, erroneously called "cones of the clypeus" by Slingerland and "face lobes" by Scott,[1] are found, one on each side of the median line, below the epicranium (*28*-4, *fc*). As seen from the front (*28*-5) they diverge from the vertex just beyond the front ocellus. They are separated from the cheeks or genæ by a curved suture, which appears somewhat ovate when the cones are viewed from below. This suture could be made out much more easily on the cephalic than caudal surface of the head.

The genæ (*28*-1, 4, 5, *g*) extend from the cephalic edge of the epicranium down on each side under the compound eyes and fuse with the caudal, folded portion of the epicranium. Between the cones and the compound eyes is the antennal socket (fig. 5, *as*), which is quadrate in shape, with angles much rounded, and with a blunt projection, *p*, breaking into it on its caudal edge, which is concerned with the articulation of the basal segment of the antenna. The aperture filled by the prosternum, procoxæ, frons and mouth parts is similar in shape to that of the epicranium but narrower. On the edge of the gena, midway between the vertex and the compound eye on each side, is situated a sharp projection (figs. 1 and

1. Insect Life, vol. V, pp. 229-230.

5, *y*), forming the attachment for a membrane which runs caudad between the front coxæ, and which will be mentioned more fully later. The outline of the compound eye is somewhat more angular than rounded, viewed from either the front or the rear.

In my study of the sclerites of the head I have followed Comstock and Kochi, and my conclusions for *Pachypsylla* agree largely with the facts recorded by them.

ANTENNÆ.

The antennæ are filiform, rather stout (a characteristic of the genus *Pachypsylla*), and average 0.83 mm. long. They are 10-segmented (*28*-3). The relative lengths of the ten antennal segments on the basis of the length of the first segment may be represented thus: 1, 1, 2, 1.2, 1.1, 1.2, 0.8, 1, 0.7, 0.4; the second segment is wider distally than proximally and is distally notched; the fourth, fifth, sixth, seventh and eighth segments are constricted proximally; the tenth segment is the smallest segment and bears at its distal end two stout, blunt, diverging spines (fig. 12), which are about as long as the segment and appear to be hollow. The last few segments are compressed dorsally.

The cuticula of the first two segments is very deeply rugose, forming scales, which on the second segment become longer at the distal end (*28*-3). The surface of the remaining segments is covered with deep, transverse corrugations (*28*-6), which give to each segment a sharply serrate lateral edge, the teeth pointing distad. A fringe of sensory hairs is found on the distal ends of the segments, and a few scattered along their surfaces, the tenth segment being without conspicuous hairs. Figure 9, plate XXXIV, shows the last four segments, with their corrugations and the terminal spines, while figure 6, plate XXVIII, is of the articulation of the third and fourth segment, showing the sensory hairs and the cuticular structure.

MOUTH PARTS.

The suctorial mouth as found in the homoptera, and as described by Meek (1903) and others, consists of labrum, epipharynx, labium, hypopharynx, and setæ. These parts are all represented in *Pachypsylla*. Closely associated with them are the frons, clypeus, mandibular and maxillary sclerites, and tentorium, corresponding in position to those in the cicada.

These parts are so closely associated with the mouth parts proper (labium excepted), forming as they do a distinct region of the head, which is torn loose in dissection as a single complex of sclerites (*32*-1)., that they will be described in this connection.

On account of the vertical position of the epicranium, the mouth parts assume an orientation by which the frons, clypeus, and labrum are almost horizontal, their distal ends projecting caudad (*28*-5). The basal portion of the labium has a similar orientation, but distad of its bend (*29*-2) it observes a general ventral direction, though possessing some latitude of movement cephalad and caudad.

Frons.—The frons is the largest and heaviest sclerite in this region. Viewed from in front (looking dorsad) it is seen to be obovate in outline (*29*-3). Viewed from the side (fig. 1) its ventral outline is strongly rounded basally, with a dent at about the beginning of the distal third. Its basal edge is thickened (figs. 5 and 1) and continued laterally into processes (figs. 5, 3 and 1) which join the lateral ends of the rod-shaped tentorium, *t*, and the chitinized rods, *cmx*. At the place where the rods *xyz* (fig. 5) above mentioned leave the frons at *x*, same figure, there springs a ligamentary process (*28*-5, *lp*), which runs cephalad and dorsad of frons, forming a small plate above the latter, and this plate in turn is connected to the vertex by two small ligaments. These are for the attachment of the frons to the head, still leaving some opportunity for motion. The frons is rugose-punctate of surface.

Clypeus.—The clypeus (*29*-1, 3, *c*) is about one-third as long as the frons. It is more or less rectangular as viewed from the front, broader at proximal end, and its lateral edge is bent dorsad, thus partly enveloping the stylets or setæ. The slightly curved suture between this sclerite and the frons was clearly marked in most specimens examined, though in a few it was not readily discerned.

Mandibular and Maxillary Sclerites.—Between the lateral edge of the frons and the rod *cmx* (*29*-1), and bounded proximally by the arm of the frons which joins *cmx*, is a more or less circular foramen through which the bases of the setæ may be seen (figs. 3 and 1, *for*). This foramen is bounded distally by two sclerites; the proximal is crescent-shaped and is known as the mandibular sclerite (fig. 1, *mds*); the distal is

triangular and extends forward about as far as the end of the labrum and is called the maxillary sclerite (fig. 1, *mxs*). The end of this sclerite has a rather slender, curved portion at its apex, called the "maxillary process." These two sclerites are shown in figure 3 in ventral aspect, and in figure 1 in lateral aspect, where the clypeus, labrum, setæ, etc., have been bent ventrad in order to show the parts free and not overlapping. The edge of the maxillary sclerite and maxillary process are also shown in figure 5 looking ventrad. According to Smith (1892) these two sclerites represent the true mandibles and maxillæ, the setæ not being considered as such.

MOUTH PARTS PROPER. *Labrum.*—The labrum (*29*-3 and 1, *lab*) is only about half as long as the clypeus and differs in shape from the labrum of the cicada in that instead of being a narrow, pointed process, it is, as viewed from in front, rectangular in general shape, slightly longer than broad, with distal corners rounded. It is not so flat as in the cicada, but its lateral edges are bent dorsad in the same manner as those of the clypeus, so as to partly surround the setæ and the pharyngeal canal. At the proximal end of the labrum is found a slightly curved suture between it and the clypeus. This suture was very hard to make out, and the two sclerites in some specimens appeared almost as if fused. Viewed from one side, the ventral outline of the labrum is seen to be slightly convex, with the distal portion bent somewhat ventrad. Marlatt's nomenclature makes the frons the clypeus and the clypeus and labrum a two-piece labrum.

Epipharynx.—Situated under the labrum (*29*-2, 3 and 1, *ep*), and shorter than the same, is an indistinct organ, the epipharynx. In the psyllid this organ is a delicate, fleshy, tongue-like structure, more or less triangular in shape, with a blunt tip, extending as a sort of outgrowth from, and extension of, the labrum. It appears as if it were a prolongation of the labrum, and it was difficult in most cases to determine where the one ended and the other began. The epipharynx is pressed tightly upon the upper surfaces of the setæ, surrounding them somewhat on the sides, and thus supplements the labrum in keeping them together to form a tube.

Labium.—The labium is attached below the hypopharynx, on the lower side of the head (*29*-1, *labi*, and *34*-6). This attachment is by means of a delicate membrane made fast to the

edge of the foramen next to the frons, which is easily torn away in dissection. At first the labium is merely a membranous band with only very slightly raised edges, which in this region of the organ are somewhat chitinized. These edges gradually become more raised and lose their chitinization until finally a little before the bend in the labium these edges become broad flaps which come together, and from this point to the tip there is left only a slit (*29*-4). The epipharynx lies naturally against the floor of the labium, but it can be lifted clear, together with the remainder of the parts, for some distance from this position. The first or basal segment of the labium is membranous, not chitinized, since it is so well protected between the procoxæ in a membranous fold. Each procoxa is placed very close to and almost fits the foramen laterad and dorsad of the frons (*29*-1, *for*). The first segment of the labium lies between the front coxæ, embedded in a membrane, and these coxæ almost meet over (ventrad of) it (*29*-2 and *31*-1).

The attachment of the labium to the prothorax, in this case to the region between prothorax and mesothorax, typical of the Homoptera, is very strong as compared with that between labium and head. In fact, in most cases when the head was removed from the rest of the body the labium remained fastened to the thorax but tore loose at its base from the head. Meek mentions such a condition as present in the cicada, calling the structure on the thorax to which the labium is attached a "collar," describing it in the following words: "A heavy membrane attaches the labium to a chitinized collar of the thorax." In *Pachypsylla* this collar is a chitinized process (*27*-4) embedded in the membranes between the prothorax and mesothorax (*29*-2, *p*). This process consists of two heavily chitinized structures, flattened and concave at their distal ends and large and swollen at their proximal ends, which are connected by a curved, chitinous rod as a sort of yoke, which is immediately under or dorsad of, and partly encircles, the labium just cephalad of its bend (*29*-4, *b*). The bases of this process are embedded in the membrane dorsad and somewhat caudad of the cephalic margin of the mesothorax, from whence the process projects ventrad and cephalad. The distal, parallel ends of these are roughened on their edges and hollowed out to form a groove, which, assisted by membranous

attachment, holds that portion of the labium just beyond the bend. Connected to the distal ends of these processes are membranes which run cephalad between the bases of the prothoracic coxæ, surrounding the labium, to form a sort of fold or groove for the same. This arrangement may be seen in figure 2, plate XXIX, in diagram, *m* representing the membrane surrounding the labium, *p* the process holding labium to thorax; the position of the labium and setæ may also be seen. Figure 1, plate XXXI, a cross section through the base of the mouth parts and procoxæ, corresponds roughly to Meek's "Fig. 13" for *Cicada,* and shows the great similarity between the two forms. The bases of the membranes surrounding the labium are here illustrated.

The labium is slitted throughout its entire length. At its base, where it is almost flat, it has only short, low, lateral edges or flaps, and hence is broadly open, and the upper parts of the mouth fit into this (*29*-2, 4). The labium, epipharynx and setæ all lie on the floor of the labium. Just at, or a little beyond, the end of the epipharynx the lateral flaps become larger and converge, their wavy margins fitting rather closely together. From here on to the end of the labium these flaps do not diverge again. Figure 6, plate XXXI, represents a cross section of the first segment of the labium just beyond its bend. Here the slit is seen to be held together by means of grooves and ridges. There is also a depression on its caudal wall. The lining of the labial canal is somewhat chitinized. On each side of the canal are found two longitudinal muscles, *m* of the same figure. The first labial segment is much roughened distally; the second is quite short, chitinized, and bears sensory hairs at its distal end; the third segment is heavily chitinized, with a pointed tip ending in two lateral, tonguelike processes. The lateral outline of these is seen in figure 2, plate XXXI, and in cephalic aspect in figure 3. The most notable feature of these processes is the three large sense organs on each—large spines on pegs. These same three sense organs are found on the labium of Aleurodidæ. This segment also bears several large sensory hairs, two of which are much longer than the segment itself.

Pharynx.—This is tube-shaped, chitinized, spreading somewhat at its cephalic end (*29*-5, *p*). Its ventral surface is supplied with eight pairs of muscles and tendons, which run

to the inner surface of the frons. At its distal end the pharynx fuses with the hypopharynx and hypopharyngeal lamellæ. The organ is heavily chitinized and thick-walled for some distance, but soon becomes narrower and, losing its chitinization, proceeds caudad until about the middle of the back part of the head, where it turns abruptly caudad and enters the thorax to become the œsophagus.

Mandibles and Maxillæ.—In dissecting the mouth parts the labium is generally torn loose from its connection below the hypopharynx and other parts and left connected to the thorax, as already mentioned. The setæ, however, remain fixed firmly to the upper parts of the mouth (*32*-1) and can be separated and torn loose from these parts only with difficulty. They are held together by the labrum and epipharynx above, the maxillary sclerites and maxillary processes on the sides, and by the hypopharynx below. From this point the bases of the mandibles and maxillæ diverge cephalad and laterad in a manner which has aptly been compared to the form of the letter "Y." The orientation of these parts was best seen in either a lateral view of the frons, clypeus and other parts removed from the head, or by examining the parts in such a position as to look down on the bases of the setæ in the direction of their distal ends. In such a position this divergence, which takes place immediately cephalad of the hypopharynx and other closely enveloping parts, can be plainly seen. The bases of these setæ (*26*-8, 9) are hollow, funnel-shaped, heavily chitinized, and attached to the other parts by tendons and muscles. One pair of these setæ, from their cephalic position, were recognized as the mandibles, and when dissected out were found to surround the other pair of stylets throughout their entire length, their slightly concave inner surfaces fitting closely against them. This latter, inner pair represents the maxillæ. On dissection they were found to be held firmly between the mandibles on each side and were difficult to separate. The mandibles are thicker than the maxillæ, but not so wide. Their relative shapes can be seen in cross section in *31*-5. As in the cicada, the setæ shortly after leaving the head begin to curve so that the mandibles are above and below the maxillæ instead of laterad of them. This curving was seen in sections distad of the bend of the labium and had begun in the section from which figure 5 was drawn. In this figure the

lumina in each mandible may be seen. These may also be seen running to the tip when the mandibles are viewed extended, as they are generally filled with air, which renders them visible. No indication of lumina could be found in the maxillæ. They, however, by their concave surfaces fitting together, form a canal through which the plant juices are sucked. The tip of a mandible is very slender, sharp, and sickle-shaped, the convex side bearing blunt serrations, the teeth pointing proximad (*26*-7). The tip of a maxilla is of similar shape but with a sharp projection on the convex side some distance from the apex (fig. 6). The apices of these setæ are so transparent that the details of their structure were difficult to discern clearly.

The homologies of the hemipterous mouth have been much discussed in the past, and the opinions held have been various. I have followed the nomenclature used by Meek for *Cicada*, which seems to be in harmony with late investigations along this line. In their place I have compared the parts of the mouth as seen in *Pachypsylla* with the corresponding parts in *Cicada*. I also found in my work that comparison with other homopterous forms was helpful, showing the close relationship of the Psyllidæ to the other families.

The labium of the Aphididæ is quite similar in general structure to that of *Pachypsylla* except in relative length and number of segments and in the fact that it does not possess the bend characteristic of the latter insect.

The mouth parts, exclusive of the labium, are almost identical with, though larger than, those of the Aleurodidæ which I have examined. The same sclerites are present, arranged similarly, though somewhat differently shaped. The labrum is much shorter and smaller proportionately than in this family, and the setæ seem to be relatively shorter. The end of the labium has the same lateral processes, but these are relatively smaller. The Aleurodid labium has a bend similar to that of *Pachypsylla*.

The coccid mouth parts also correspond in many ways. Here the labium is very short and the setæ are retracted into a special pouch when not in use. The parts exclusive of the labium are similar in general structure to the same parts in *Pachypsylla*. Berlese's nomenclature and figures in his work on Italian Coccidæ were very useful to me. According to this,

the clypeus or *ipostoma* (epistoma) corresponds to the frons of *Pachypsylla,* the two terms "ipostoma" and "clypeus" being generally used interchangeably by him. *Cmx* of my figures is the *ipostoma; xyz* is the *rod-shaped apophyse of the clypeus;* the thickened, basal edge of the frons, *z,* is the *transverse bar of the ipostoma;* the opening, *for* (*29*-1), is the *foramen of the ipostoma.* The structure which Meek calls the tentorium is designated by Berlese the *transverse branch of the ipostoma.*

THORAX.

The thorax as described by Riley: "Pronotum moderately short, of equal width, slightly emarginate behind, steeply ascending posteriorly; lateral impressions sculptured and colored as the head; well marked. Dorsulum well developed, thrice as long as the pronotum, and about twice as wide as long; posterior lobe distinctly longer than the anterior; hind margin sinuate each side and truncate at middle; surface finely alutaceous; color, light brownish yellow with a large brown apical spot divided by a yellow median line. Mesonotum convex, wider than head, sculptured as dorsulum, with four vittæ (longitudinal) of brown or greenish-brown color, the outer ones usually wider than the inner ones, all bordered and divided transversely by lines of brighter yellow."

Prothorax.—Viewed from above the thorax is seen to be composed of a number of sclerites, as seen in *27*-3, A and B, which upon closer examination and dissection may be shown to make up the three typical regions of the thorax. In the prothorax there is only one sclerite composing the tergum—the pronotum (*27*-3, A and 31, *pn*). This is collarlike, steeply ascending, as seen in the longitudinal section (fig. 3 B), somewhat wider at the middle than laterad, where an obscure suture divides it from the pleural sclerites. This is shown in plate XXVII, fig. 1, and plate XXXV, fig. 12. The proepisternum and sternum are very closely fused and the suture is scarcely evident. The proepimeron (*27*-1, *em 1*) is a rather wedge-shaped piece, rounded on its ventral end, lying back of the ventral portion of the pronotum and the dorsal portion of the proepisternum. Situated in the pleural membrane beneath the proepimeron is the prothoracic spiracle, *sp.* As seen in *35*-6, the prosternum is only slightly developed, its cephalic edge on each side being produced entad into a slender portion. The prothoracic coxæ are large and occupy, together with the

labium, which is imbedded in a membranous fold between the former, most of the prosternal region, leaving the prosternum to develop mostly on the sides. The "collar," already described as a chitinized process holding the labium to the thorax, may be of the nature of the apophyse as seen in the endoskeleton of the mesothorax.

Mesothorax.—The mesothorax is next in complexity of structure, naturally being larger and more complex than the prothorax, as it bears, besides one pair of legs, the fore wings. The tergum is composed of three sclerites (*34*-2, and *27*-3, A, B). Edwards thus describes the mesotergum of the Psyllidæ: "Mesonotum large, generally suborbicular; a portion of its area in front in the shape of a broadly truncate triangle (the *dorsulum*), separated from the remainder by a distinct suture, and a small crescent-shaped piece projecting from the middle of its hind margin (the *scutellum*), also marked off by a suture."

The dorsulum (*27*-3 A and 1) is in shape an equilateral triangle, truncate at its angles, with the edges of the lateral truncations notched. The posterior margin is not straight, but produced on each side into a small projection midway between the median line and the edge of the sclerite. The anterior third of the dorsulum is covered by the posterior edge of the pronotum (fig. 3 A).

The mesonotum (*27*-3 A and 1, *mm*) is the largest sclerite of the thorax, ovate, convex, and about twice as wide as long, with anterior margin almost straight and posterior margin deeply convex. The sclerite is laterally narrowed to a blunt, notched point, which is best seen in lateral view (fig. 1).

The scutellum (figs. 3 A and B, *scu*, and 1) is, viewed from above, ovate, twice as wide as long, lateral edges rounded, anterior margin slightly concave and posterior convex and hollowed out at the median line. The structure of the pleurum of the mesothorax is exceedingly complicated and the sutures are all indefinite. The structure of the same is shown (partly diagrammatic) in figure 1. The suture between the mesosternum and the sclerite just dorsad could generally be made out. This latter sclerite I take to be the mesoepisternum, *es 2*. The mesoepimeron, *es 2*, is a very irregular, much folded sclerite intimately connected with the inwardly extending endoskeleton (fig. 2, *es 2* and *end*). These pleural sclerites are so folded

and fused one upon the other that practically only the region of each could be indicated roughly in figure 1. The origin of the anterior wing may be seen in figure 1, *bp*. Just cephalad of its base are two fleshy processes—the cephalic, larger and somewhat reniform in shape; the articulatory epidemes, *artep*. Cross sections show the larger epideme to be almost spherical, with a broad, short base or pettiole.

The mesosternum is rectangular, wider than long, anterior margin somewhat convex, with corners rounded. The coxal cavities or acetabula are large, ovate, and are situated on the posterior margin (*35*-11).

When the mesothorax is dissected free from the other segments, and viewed from behind, the endoskeleton is plainly seen. I shall not attempt to give the orientation and detailed description of its different parts, which may be seen in *27*-2 (partly diagrammatic). This internal skeleton is a complex of plates and rods, braced in all directions, and fused with the outer sclerites of the segment. Three different internal projections may be seen, dorsal, lateral, and ventral. The dorsal piece, the phragma, *phrg*, is a symmetrical, transverse plate projecting ventrad. A similar structure in the mesothorax of a stag beetle is figured by Packard (Textbook of Entomology) and called "Diaphragm for the attachment of the tergal muscles of the metasternum." On each side there is a simple projection which seems to correspond to the apodeme, *apod*. The lower projection or apophyse ("medifurca," according to Packard) is seen at *apoph*, and in *35*-11, and is shaped like a letter "Y"; its dorsal edge is hollowed out, this hollow together with a similar one on the lower edge of the phragma above giving passage to the digestive system, etc. (*27*-33, *c*.)

The mesothorax is built for great strength, the sclerites being much fused and the internal structures all large and heavy. Although this segment carries the anterior wings, which are used mainly in flight, I have no evidence that this insect is a very strong flyer; on one occasion a specimen was captured on the top of a high building, but probably it was carried to such a height independent of its own flying powers, by a strong wind blowing at the time.

Metathorax.—This segment is the strongest in structure of the thoracic segments, and the endoskeleton and external sclerites are so strongly fused that the homologies of this region present a great many perplexing problems. I shall proceed to

describe the different parts as I have found them, together with my interpretation as to their homologies. The structure of the notum is not so difficult to determine. Three sclerites are plainly made out (*27*-3 A). The anterior of these is crescent-shaped, and in life is concealed by the scutellum of the mesotergum. The dorsal portion of the second sclerite is a small ovate plate, while the third and posterior sclerite is rather broad, its posterior margin somewhat indented and its lateral margins concave.

The metasternum (*27*-5; *30*-8; *31*-7, *str*) is best developed anteriorally where it is connected with a very light, narrow, median portion between the acetabula, which in turn is connected with and almost seems to be a part of the metafurca, *mf*, of the endoskeleton. Closely connected to the internal pieces of the latter, and separated from the sternum by an obscure suture, is a sclerite whose dorsal end fuses with the other parts. This probably represents the region of the metaepisternum (*31*-7, *es 3*). The portion (x) in figure 7 which runs ventrad and entad to join a part of the metafurca has notches on its ventral edge at x, and with these notches articulates the end of a complex of sclerites extending down the side and across the ventral surface of the segment (*27*-5 and *31*-8). Much difficulty was found in homologizing these sclerites, authorities differing as to the names of some of the parts. Upon tearing loose this complex carrying the metathoracic leg from its attachment at x and y (*31*-8) and examining it under a high power of the microscope, its structure could be made out. It is composed of five sclerites. Entad (somewhat caudad and dorsad) is a more or less crescent-shaped sclerite (fig. 8, *str*). This I believe to be a part of the sternum. The next sclerite, *mer*, extad and cephalad, is of a similar shape but bears a blunt projection or tubercle. Authorities differ as to what is the homology of this part. Westwood says: "Beneath, the epimera of the metathorax are singularly produced behind the place of insertion of the hind legs (which are pushed forwards), and terminated by two strong spurs." Edwards states: "Mesosternum produced behind into two large, sharp spines." Riley states: "Metasternal processes cylindrical, hardly narrower toward the tip, which is obtuse, not pointed." I find a similar structure in all the Cicadidæ which I have examined. In "Les Cicadines D'Europe," translated from the German of Fieber by Reiber (1875), in the discussion of the general structure of

the Cicadidæ, under legs, this sclerite is called the "meracanthus" ("A la base des hanches et spécialement aux postérieures, naît, visible chez les Fulgorides et remarquablement développée chez Cicada, une épine subulée, au lobe triangulaire, lancéolée, cornée, qui est encore assez distincte aux hanches intermédiaires, Le Dr. Hagen [Die europ. Cicaden, Stett. ent. zeit. 1886] appelle *trochanter* [Klappe] cet appendice corné qui doit être désigné sons le nom vrai de *Meracanthus*, pl. 10, fig. 9, b, car le trochanter n'a pas d'apendice").

Focusing upward with the high power, the next sclerite, also crescent-shaped, with parallel edges, which is seen to be the next extad, comes into view (fig. 8, *em 3*). It is this sclerite which articulates at *x* and *y* (figs. 7, 8). This I believe to represent the metaepimeron. Cephalad and laterad of these sclerites is a platelike piece, the cephalic end of which bends dorsad and entad, and forms a ring. This structure is seen in figure 8, *cox*. On this ring, the trochanter articulates (also upon the end of the episternum), and since this sclerite is the only one which in any degree approaches the typical cylindrical coxal form, being in this case a sort of ring at its end, I take it to be the coxa. Entad (dorsad) of this, and slightly cephalad, is an accessory sclerite (*35*-8 and 9, *scl*), a rod whose caudal end is flattened out into a plate to which are attached muscles that arise from the inner surface of the meracanthus, or epimeron (which of these two, I am as yet unable to state). The cephalic end is connected to the cephalic edge of the trochanter and serves to pull it towards the body. Its position is shown in figure 8, plate XXXV.

Turning now to the internal structure of the metathorax, which is best seen from the front, when this segment is severed from the others the metafurca (*30*-8; *31*-7; *27*-5, *mf*) are the most prominent features. The two large forks which proceed dorsad and caudad are connected with the lower surface of the tergum. The whole endoskeleton is so closely fused with the sclerites of the metathorax that it cannot always be separated from them. This internal structure is large and heavy, and by bracing all parts makes the segment exceedingly strong and rigid.

The structure of the pleural sclerites in a species of Aleurodid which I examined was also found to be very complex, there being a large number of sclerites homologous to those found in

Pachypsylla, and a careful comparison of the two forms would throw much light on the question.

The metathorax is not so heavily braced as in *Pachypsylla,* but the coxal region is still well developed. A study of the psyllid pupa would probably show much of interest in this connection, as these parts above mentioned are all represented there but somewhat simplified. The folding and fusion of parts in the adult, and the presence of a heavy, braced endoskeleton and the complex articulation of the trochanter of the metathoracic leg, are all specializations to render possible and increase its jumping power.

My studies on the thorax of the Psyllidæ agree with the recent articles by Snodgrass (1909), in which the old theory of Audouin making each tergal segment to be composed of four primitive sclerites is discredited; I have been able to find no more than three sclerites composing the mesoterga and metaterga.

WINGS.

I. VENATION.

The wing venation of the Psyllidæ seems never to have been reduced to any uniform system such as that of Comstock and Needham (1898-'99). I find the venation figured by Mally, Edwards, Slingerland (1896) and others, but the nomenclature is not uniform and is of a special nature. I have attempted to reduce the venation as seen in the insect under discussion to the system of Comstock and Needham, above mentioned. In this study my first conclusions as to the homologies of the veins were arrived at through the study of adult wings alone, but later I have made use of nymphal wings and wings of newly emerged adults.

On March 6 a large number of pupæ of *Pachypsylla celtidisgemma* were procured from their galls on the stems (lateral buds) of the hackberry, some seven or eight being found in each large-sized gall. Their wing pads, after soaking for about a day in dilute formalin, were removed, mounted in dilute glycerine, and studied with special reference to their tracheæ. As soon as I had begun this study I found that my conclusions arrived at earlier were borne out in almost every detail by the number, position, character, etc., of the tracheæ of the nymphal wings, these tracheæ corresponding to the veins of the adult wing.

Venation of Nymphal Wing Pads and Wings of Newly Emerged Adults.

Fore Wing (*26*-3 and *32*-8).—The costa, *C*, rises from a large tracheal trunk from the thorax, proximad of the radius and subcosta (fig. 3). It follows the anterior margin, but drops down at the region of the stigma and fuses with the subcosta.

The subcosta, *Sc*, and radius, *R*, are fused throughout the basal third of the wing, and the free portion of the first-named vein is comparatively short, as it soon fuses with the costa.

The radius is represented by a single trachea, and at its base, where it is fused with the base of the subcosta, it rises from the large tracheal trunk, distad of the origin of the costa (fig. 3).

Media and cubitus, *M*, and *Cu*. The media rises from the main trunk just cephalad of the base of the cubitus and distad of the base of the subcosta (fig. 3). It is two-branched and shows its double structure throughout the distal half of the pad, the two branches being close together and parallel for some distance. The three tracheæ, the subcosta plus radius, the media and the cubitus run parallel throughout the basal third of the wing. In normal position, these three tracheæ are very close together, as in figure 8, but in the diagram (fig. 3) they are represented more widely separated to show their connections with the main tracheal trunk from the thorax. The occurrence and relative positions of these three tracheæ are of the greatest importance in correctly determining the homologies of the adult veins, as the upper of these branched veins, formerly called the "upper branch of the cubitus," arises from a trachea distinct from the true cubital trachea, and therefore cannot be a part of the cubitus, while the trachea representing the subcosta plus the radius fused is distinct from those of media and cubitus, though all four veins appear as a single vein in the basal portion of the adult wing. Both media and cubitus are two-branched, their distal ends bending so as to run parallel with the costa for some distance before fusing with it, forming at some places as many as three parallel or more or less intertwining lines of tracheæ (fig. 3).

The anal fold or "claval suture" (fig. 3, *af*) is present as a distinct trachea which fuses at its distal end with the second branch of the cubitus and the costa near the posterior margin. Only one anal vein (fig. 3, *A*) could be made out, but as this

trachea was torn more or less when the fore wing pad and the hind wing pad, which are grown together at this point, were separated, such evidence in itself is not conclusive. However, from my studies I have every reason to believe that normally only one anal vein is represented. Likewise, the basal connections of the costa of the posterior margin and the trachea of the anal fold to the main trunk from the thorax could not be accurately determined.

For the further study of the development of the venation, a number of *Pachypsylla celtidis-mammæ* which had emerged during the fall of 1908 were thrown into weak formalin immediately after emergence, before the chitinized veins had been laid down (*26*-4; *32*-9, 10 and 11). In one specimen (*26*-4 and *32*-9) the wing was still delicate and transparent, with its edges crumpled and folded, and the veins still practically in their tracheal condition, while in other specimens the wing membranes had hardened, the pattern gained its pigment, though still light, and the veins fully formed but with the tracheæ in some cases visible within them (*32*-10 and 11). In the youngest specimen mentioned above the three parallel tracheæ of the subcosta plus radius, media and cubitus were strictly separate and corresponded in position to those of the nymph of *P. c.-gemma*. The distal ends of the veins, becoming lost in the folds of the margin of the wing, could not be traced. The position and direction of these tracheæ here were more closely like the veins found in the adult than were those of the nymphal wing pads.

These studies aided me much in studying the development of the tracheæ into veins, and the coalescence of two or more of the former into one vein, as seen in the case of the subcosta plus radius, media and cubitus. In some specimens these could be seen to be still single and parallel until they reached the internal trunk (*26*-4 and *32*-9). The radius and subcosta fused (*32*-10) was on the cephalic margin of the compound vein in process of formation, the cubitus (fig. 11) being on the caudal margin.

The vein in the anal fold could still be plainly seen (*26*-4), but its basal connection was not made out. Since there is no thickening of the wing here, as soon as the air leaves this trachea the only suggestion of a vein that is left is the transparent "fold."

Since there is so little chitinization and thickening of the membrane around the tracheæ of the hind wing, these can be studied best in specimens such as the above, where air in the tracheæ renders them visible. This is especially true of the costa, subcosta and vein in the anal fold. The subcosta cannot be made out in the adult hind wing, and has not been figured for it, but shows plainly when filled with air. By placing a piece of black paper under the condenser of the microscope the veins appear a glistening white, and under the low powers are much more easily studied in this manner.

An interesting point I observed in the hind wing was the presence—in one specimen—of what should probably be regarded as a "sport" vein (*26*-2, *sv*). It is connected with the anal vein and also fuses with the costa. Since I have found in one hind wing of two specimens, both male and female, the radius forked, as is the case with the normal cubitus, which branch, though a "sport," probably points back to a former two-branched condition of that vein as seen in the fore wing, this vein above mentioned may show the same condition for the anal wing, and represent the second anal vein. I find under "Psyllidæ" in the "Zoölogical Record" for 1867 the following: "From the occurrence of irregularities in the venation of the wings of this species, [*Anisostropha ficus* Linn.] he [Frauenfeld] takes occasion to remark upon the frequency of such irregularities among the Psyllidæ; the variation is almost always confined to one wing."

Adult Venation.

Fore Wing (*27*-6).—The costa can be easily traced around the entire margin of the wing and is very thick at the basal portion of the anterior edge. All the rest of the veins except the anal arise from a single main trunk, which is the main support for the wing. This trunk is composed of the three tracheæ mentioned above, fused—the subcosta plus radius, media and cubitus. The subcosta and radius are fused as far as the stigma, *s*, where the subcosta runs up toward the costal margin, forms the lower margin of the stigma, and meets the costa somewhat proximad of the apex of the wing. The radius is composed of a single vein, probably representing R 4 + 5. At about the middle of the cell, *I*, a vein leaves the main trunk which divides into two branches, each of these again dividing once. The two upper branches represent M 1 + 2, and M

3 + 4. In one specimen of *Psylla coryli* I found that on one wing the media was single instead of two-branched, but never found such a case in the present species. The two lower branches above mentioned are *Cu 1* and *Cu 2*. Below this is what is called the "claval suture," corresponding to the anal fold (fig. 46, *af*). The region posterior to the anal fold or claval suture is generally called the "clavus," from the corresponding region in heteropterous wings, *cl*. One anal vein is present; this, by a dorsal and cephalic folding over of the distal half of the margin of the clavus, takes the place of the costa at this point (that is, forms the posterior edge of the wing here), the two veins appearing upon first observation to have crossed. This condition was also observed in the nymphal wing pads and in the wings of newly emerged individuals.

Hind Wing (*27-7*).—This is more simple in venation than the fore wing. The costa soon becomes weak and indefinite. The subcosta is not visible except in newly emerged individuals where the tracheæ are filled with air, and the radius is seen as in the fore wing, as a single vein. The media is also a single vein, though in two specimens I found it two-branched in one wing after the fashion of that vein in the fore wing. The cubitus has two short branches. The claval suture and anal vein are practically the same as those in the fore wing, only there is no folding over of the posterior margin of the clavus.

The adult wings as above described are specialized by reduction, the coalescence of veins being outward.

According to Mally's nomenclature, the common base of the media and cubitus which joins the subcosta plus radius is known as the "Petiolus cubite," *Pc;* the media and cubitus before branching are known as the "first cubitus" and the "second cubitus," and their branches the "first, second, third and fourth furcal veins." The presence of a media is not recognized by him.

Edwards calls the media and cubitus the "upper and lower branches of the cubitus," and the "Petiolus cubite" of Mally the "Stalk of the cubitus." He mentions no media.

Woodworth (1906) adheres to a nomenclature somewhat different. According to this, the media and cubitus are called the "independents" which "appear as a twice-forked branch

from the primary," the fact that these veins are distinct, arising from separate tracheæ—as I have shown—not being recognized.

The Psyllidæ are the highest of the group Phytophthires of the Homoptera. These all have simple wing venations, that of the Coccidæ being the simplest. Woodworth says of these: "The venation of the Phytophthires has a nomenclature of its own, not relating it to any other groups, the only investigator who has attempted to homologize the veins being Redtenbacher. This author admits to only two branches as belonging to vein V (corresponding to my independents) [vein *m*] in the Psyllidæ, and sees none at all in the Aphididæ."

II. PATTERN.

Fore Wing.—I quote Riley's original description of the wing markings of this species: "Front wings narrower and, therefore, apparently longer than in *venusta,* very little wider at terminal third than at basal third; costal margin at base but slightly subhyaline, more or less densely covered with small, brownish, scalelike specks, as follows: an oblique and gradually narrowing band (extending from the tip of the pterostigma to near tip of radius), which runs across the wing to the tip of the first furcal, is usually freer from these dots than the rest of the wing, while its edges are usually more crowded with the dots, so as to bring the pale band into greater relief; quite frequently there is an intensified patch of brown about discoidal part of subcostal vein and at all vein furcations; also, the terminal space outside of the pale oblique band is uniformly dark, but with three marginal pale spots (one on each side of the cubital, second marginal and discoidal cells), always more or less evenly speckled; exceptionally, both inside and outside the oblique band, there is a border of variable extent, of a uniform dark brown color, not composed of small dots."

There is great sexual difference in color pattern and in intensity of markings, as seen in figures. The dark border of the light band mentioned in Riley's description is generally very weak in the female, sometimes almost obsolete, except where it crosses the veins, as in figure 6, plate XXXIII. In general, the wing of the male is darker and more heavily marked than that of the female. Also, the spring forms of both sexes are said to be darker than those that emerge in the fall and hibernate over winter.[2]

2. Insect Life, vol. V, p. 227.

In the males there is generally a large dark spot between *Cu 1* and *Cu 2*, and on and below the radius proximad of its fusion with the subcosta, this spot tending to spread across cell I. These spots, proximad from the stigma, tend in the female to be reduced to dusky portions only a little darker than the surrounding parts, the former being almost indistinguishable and the latter confined to a border to the vein. The three marginal spots mentioned by Riley are generally more distinct in the male. There is a great deal of individual variation in the wing markings as to the number and arrangement of the small spots composing the pattern, no two individuals showing precisely the same combinations. Figures 1 and 5, plate XXXIII, show how this pattern is produced, and incidentally the difference in shape of the apices of the male and female wings. Figure 4, plate XXXIII, is another view of the pattern at the branching of the median veins, more highly magnified than the two preceding.

The upper surface of the wing is entirely covered with disk-like cuticular outgrowths about 0.005 mm. in diameter, best seen in cross section through the wing (*30*-9, *a* and *b*). These are more or less circular in outline though often very irregular. Some of these, *b*, are filled with dark brown pigment, the same diffusing slightly into the surrounding cuticula. These pigmented disks are arranged in groups of 2, 3, 4, 5, 6, 7, 8, and so on, to form polygons and other figures. These groups form the "spots" which make up the pattern, and are either distinct or banked up together to form a dark spot or band, in which case the polygonal structure is not so apparent. The following elements make up the pattern: (1) The individual pigmented cuticular processes, which I shall designate as "disks"; (2) polygonal and other combinations of these disks—"groups"; (3) arrangements of these groups making up the large and small spots, bands, etc.—"markings."

There are a great many different forms of groups produced by these disks, the principal types of which are seen on page 146. Polygonal groups predominate, though chainlike, broken, and irregular forms are also found. Groups of "two's" and "three's" arranged lengthwise with the wing are found predominating in the basal cells, while more complex polygonal figures are the rule in the distal regions of the wing. Groups consisting of only one disk were not found.

Any difference between the composition of the groups or the

frequency of certain group types in the male and the female was not found. The polygonal groups are oftener without the central disk dark than with. When this was not pigmented, the space was still clouded the same as the cuticula surrounding the pigmented disks.

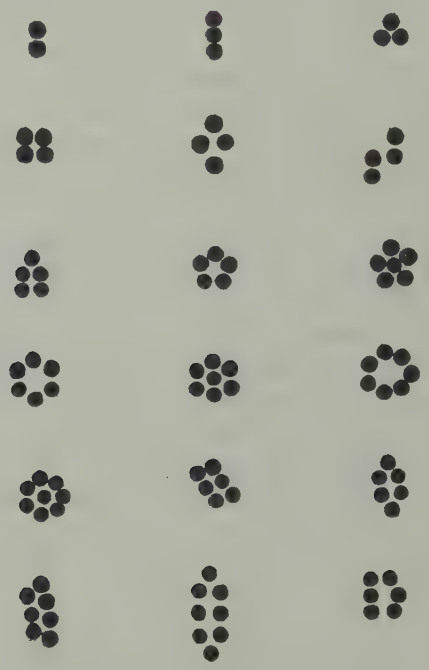

FIG. 61.—Diagram showing principal forms of groups found in the pattern.

The disks were found to be smaller proximad of the base of the wing and near the veins and the anal fold, and consequently the groups there were either of uniformly small disks or of part normal and part small-sized disks. There were no groups on the stigma; here the disks became reduced to mere low, conical projections. The anal fold was smooth and transparent, with clear-cut edges.

Cross section (*30*-9, *c*) shows on the lower side of the wing, opposite each disk, a small, blunt outgrowth, generally unpigmented.

Hind Wing.—Here the disk structure of the membrane is barely visible under favorable conditions of illumination of the microscope. Only those disks on the clavus are pigmented,

The number of groups averages thirty to thirty-five. They tend to be irregular and not polygonal. Groups of "four's" are perhaps the most common, being generally found singly, though sometimes two or three groups are associated together to form a figure, generally a chain.

III. STRUCTURE.

Fore Wing.—Of the sixty wings that I examined, the fore wings averaged 2.94 mm. long by 1.19 mm. at greatest width in the male, and 3.27 mm. by 1.37 mm. in the female. Variations in outline of the wings and in the shape of the cells were very slight. There was, however, variation noticed in the length and breadth of the wing between rights and lefts in both sexes.

In the membrane at the base of the fore wings are found two small sclerites, called by Audouin "articulatory epidemes," already mentioned (*27*-1, *artep*). The cephalic of these is seen in cross section to be more or less spherical in outline.

On each side of the wing veins is a row of rather stiff, curved hairs in circular pits, seen in *33*-1 and 5. On the anterior portion of the costa there are three rows of hairs, the anterior of which is separated from the others by a central, dorsally projecting ridge of the costa. From a point near the proximal edge of the light band, already referred to under "pattern," these hairs are found in a single row until the place is reached where the anal vein and the posterior costa seem to cross. From here on the costa bears no hairs, but in their place a row of very minute, sharp teeth on its outer edge. These teeth are also found on the edge of the anterior costa below the smooth-edged cuticular margin of the wing; they are somewhat larger here, but become obsolete a little before the apex of the wing is reached.

Upper and lower surfaces of the wing are essentially the same, as regards number and position of hairs. The structure of the membrane has already been treated. It is submembranaceous in texture.

Hind Wing.—The hind wing averages 2.5 mm. long by 0.97 mm. wide. The apical portion is wider than the basal and is well rounded. The anterior margin is fairly straight, though somewhat undulating in outline. No hairs are found on the veins of the hind wing except two or three on the fused portion of the subcosta, radius, media and cubitus, and on the basal

portion of the anterior costa, where fifteen or more—the number being variable—long, stiff hairs project cephalad, curving upward (*33*-8). The hind wings are very weak and delicate, and these hairs are of use in coördinating the movements of the hind wing with those of the fore wing, resembling somewhat the "hamulus" of the Hymenoptera.

The anterior margin of the costa is only slightly roughened —covered with low, knob-like processes, distad of the hairs— the basal two-thirds of its length, but from here on as far as the beginning of the clavus these knobs become lengthened out into spine-like scales pointing distad. The margin of the clavus is comparatively smooth except where roughened at the humeral angle.

The membranes of this wing are transparent and thin, and were often separated from each other to form a sac, when boiled too long in caustic potash. This is in harmony with the studies of Weismann, Künkel d'Herculais, Dewitz, Van Rees and Pratt, which established the fact that insect wings are of hypodermal origin, being evaginations of the integument, and the separation of these membranes through the action of caustic potash shows plainly that the wing membrane is made up of two laminæ, an upper and a lower, which are fused to one another between the veins. The veins, except the costa, are almost without chitinization, and the subcosta could be made out only when it was filled with air as in newly emerged specimens.

The fore wing is quite flat, except the clavus, which is bent somewhat ventrad, and that portion of the clavus between the anal vein and the costa is bent quite sharply ventrad, so that it is almost horizontal in position when the wings are folded along the side of the body. When the insect is at rest and the wings are in this position the anal angles of the fore wings fit up closely against the edges of the scutellum of the mesothorax, and their edges are contiguous from the distal end of the clavus to the tip of the wing. Through the gap between the claval portions of the wings can be seen the posterior margins of the hind wings, which are contiguous throughout the claval region, their anal angles fitting against the small oval sclerite of the metathorax (the second tergal sclerite).

LEGS.

The prothoracic and mesothoracic legs are essentially the same in structure, while the metathoracic leg is greatly specialized. The coxæ of the former are not free and movable, as in many insects, but immovably fixed to the thorax, and, according to Witlaczil, coalescing with it. They are greatly produced laterally, this portion being flattened and longer in the mesocoxa than in the procoxa.

The trochanters are short, cylindrical sclerites, somewhat constricted proximally. All three pairs are similar.

The two anterior pairs of femora are swollen, the outlines of their dorsal surfaces somewhat convex, and the cuticula of ventral surfaces much roughened. The femora of the prothoracic legs are somewhat longer than those of the mesothoracic pair. The distal ends are on their ventral faces deeply gouged out, into which groove, bounded by strong lateral edges, the tibiæ fit when the leg is flexed. The femora of the metathoracic legs are similar in structure to those of the other pairs, but longer and relatively more slender. There was very little variation of this part, as may be seen by the following table of measurements:

AVERAGE LENGTH.			
Male.		Female.	
Right.	Left.	Right.	Left.
0.656 mm.	0.654 mm.	0.686 mm.	0.691 mm.

The articulation between femur and trochanter of mesothoracic leg is shown in figure 78, page 150. This is similar in the other pairs.

The structure of the tibiæ is of great interest. The tibiæ of the prothoracic and mesothoracic legs are about as long as the femora, but those of the metathoracic legs are slightly longer than the femora. The distal ends of the first and second pairs of tibiæ bear a fringe of long, sharp spines which point distad, those of the prothoracic pair being slightly the weaker. The distal ends of the metatibiæ are swollen and bear nine short, thick, blunt, black spines (figs 73, 74 and 75). These spines are a part of the scheme of specialization for jumping, preventing the foot from slipping in the same way as do the spines on the grasshopper's tibiæ.

The tarsi are two-segmented. In the first two pairs of legs the second segment is larger, but the first is the larger in the metathoracic pair. In all three pairs the segments are much

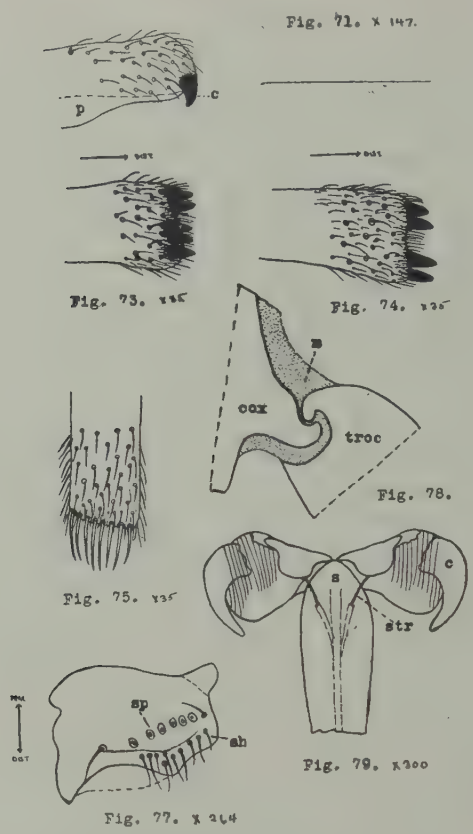

FIG. 72.—First metatarsal segment. *c*, claw; *p*, pad.
FIGS. 73 and 74.—End of metatibia showing spines.
FIG. 75.—End of mesotibia.
FIG. 77.—Metatrochanter. *sh*, sensory hairs; *sp*, sensory pits.
FIG. 78.—Articulation between coxa and trochanter mesothoracic leg. *cox*, coxa; *troc*, trochanter; *m*, membrane.
FIG. 79.—Prothoracic foot. *c*, claw; *s*, *str*, tendons moving claws.

constricted proximally. The first segment articulates with the tibia by a joint much like that between femur and trochanter. On the ventral surface of the first tarsal segment of the metathoracic leg is a soft, membranous pad, projecting distad between the two stout, laterally placed claws (fig. 72). This pad is best developed in the metathoracic tarsi and these claws are found only here.

The second segment bears the claws, which are similar in all three pairs of legs. These are short, heavy, and rather blunt,

with several small sclerites at their bases embedded in the membrane. These are illustrated in figure 79, which shows the tendons controlling their movement, and the two-lobed empodium, one lobe being under each claw. This empodium is functional, as in many insects, and is used in holding the insect to a smooth surface, as it can cling readily to a glass surface.

Femora, tibiæ and tarsi of all three pairs of legs are covered with hairs, many of which are probably tactile. Both coxæ and trochanters (except of metathoracic legs) bear hairs, the latter with one or two hairs on their distal ends longer than the segments themselves. On the trochanters is a row of oval sensory pits (fig. 77, *sp*).

ABDOMEN.

The relative shapes of the abdomen in the sexes can be seen in *35*-13 and 14 (figure inverted), also in *34*-4. The abdomen of the female is larger than that of the male and seems much longer in proportion, as the ninth segment of the male bearing the genitalia is generally carried bent dorsad and cephalad so that the supra-anal plate fits up tightly against the seventh segment, thus making the abdomen appear quite short. In both sexes it is slightly compressed laterally. According to Edwards, there are visible five segments above and six below, not counting the genital segment.

The first two segments are smaller than those caudad. "The first abdominal somite of both sexes is added to the metathorax to enlarge the springing-gear; the second abdominal somite forms a short stalk for the abdomen. . . ."—(Macloskie.)

According to Witlaczil, in the male the supra-anal plate represents the tenth somite, the ninth is not represented above, and below forms the subgenital plate; the eighth is scarcely at all developed above; in the female, the supra-anal and subgenital plates or valves represent the tenth segment.

In the pleural membrane are found seven spiracles, each surrounded by a wide, chitinized ring. The cuticula of the abdomen is punctate, not so pubescent as that of the thorax, and the membrane between the chitinized plates of each segment is covered with great numbers of minute *sensillia styloconica*. On the posterior edge of each segment is a row of

sensory hairs, in prominent pits, much more evident, however, in the male than in the female.

GENITALIA.

MALE GENITALIA.—The genital segment of the male of *Pachypsylla celtidis-mammæ* is described by Riley as follows: "Male genital segment a little longer than the preceding ventral segment, brown, shining; plate as high as the length of the segment, lateral lobe barely indicated, anterior margin straight, posterior margin very slightly oblique, *i. e.*, the plate gradually increases in width towards the tip, which is truncate and not arctuate, as in the preceding species. Forceps as in *venusta* [two-thirds as high as plate, front margin straight, hind margin slightly sinuate at basal half, tip rounded, outer face smooth and very shining]."

The genital segment of the male consists of the following parts: Supra-anal plate or "genital plate," subgenital plate, forceps or "posterior processes," and copulatory organ or "ædeagus."

The supra-anal plate is a conspicuous fleshy process attached to the anterior edge of the subgenital plate. It is generally carried at about right angles to this plate, and is shown in *35*-10 as drawn forward out of normal position. It averages about 0.48 mm. in length (measured on cephalic surface) and its greatest width is 0.19 mm. Looking cephalad at this plate it is seen to taper at top and bottom, and to be convex with rather wide flaps on its lateral edges (*30*-6, *sppfl*). At its distal end these flaps recede to the edge, where the organ ceases to be an open trough, and becomes a short, rounded, truncate, cone-shaped structure (*30*-6 and 7, *x*), connected by its cephalic wall to the basal wall of the trough below. This structure ends in a short, flaring, membranous ring (figs. 6 and 7, *a*), which is the external opening of the anus. The concave face of the plate is lined with a delicate, folded membrane, between which and the cephalic wall is situated a tube, the rectum. Almost the entire surface of the plate carries numerous long, stiff hairs.

The lower extremity of the supra-anal plate consists of a chitinized ring which expands into a rather broad, two-lobed plate, *lp*, on each side. These plates drop ventrad at their inner edges much after the fashion of a funnel, and form the base of the copulatory organ.

Extending ventrad, with its dorsal edges articulating with the lower side of each of the above-mentioned lobed plates, is a chitinized band or loop (figs. 6 and 7, *l*) extending downward almost to touch the inner surface of the subgenital plate. Between the arms of this loop the proximal portion of the copulatory organ swing, almost entirely concealed within the subgenital plate when the genital segment is telescoped into the next segment cephalad and the supra-anal plate is forced caudad. At emergence, however, the genital organs are extended and not telescoped, and at time of copulation the copulatory organ is protruded from the cavity of the subgenital plate.

Extending ventrad from the lateral plates at the base of the supra-anal plate is the chitinized couplatory organ or extremity of and sheath for the penis—"the ædeagus" of some writers. This organ (figs. 6 and 7, *co,* and *35*-7), soon after it leaves the base of the supra-anal plate, forms a sharp bend, reversing its direction to dorsad. After reaching a position about opposite the middle of the supra-anal plate there occurs a conspicuous swelling, and beyond that a joint or geniculation (*30*-6, *g*). The proximal portion of the second segment of the organ is also swollen. This segment in normal position drops ventrad. The distal end bends caudad and is swollen greatly, becoming club-shaped (fig. 6, *c*), convex cephalad, and concave caudad, this segment having a vertical orientation. The convex, cephalic face of the club is gouged out to form a deep longitudinal groove running from base to tip.

The proximal portion of the first segment of the copulatory organ is not tubular, but slitted on its convex surface, and through this slit the penis enters the sheath, *p*. The concave surface of this portion is coarsely notched or corrugated transversely for some distance beyond the bend. The remainder of the organ is tubular, the canal running through the inner half of the sheath—that is, through the cephalic half of the first segment and through the caudal half of the second segment. This canal runs into the center of the club, makes a sharp turn, and, proceeding back upon itself, curves to the convex side of the club, where it issues at the base of the club in the bottom of the groove above mentioned.

The copulatory organ is more strongly chitinized at its distal end than it is in the curved portion of the proximal segment, and along its outer surface, than on its inner. The first segment measures (from base to geniculation, the distance along

curved side being much greater) 0.31 mm., the distal segment 0.38 mm., and the club 0.12 mm.

The subgenital plate has already been mentioned in the quotation from Riley. Its measurements are as follows: Depth, 0.37 mm.; length, 0.40 mm.; greatest width, 0.26 mm.

Situated at the posterior end of the subgenital plate are the forceps (fig. 10, *f*, and *35*-15). These two pieces are somewhat swollen at their bases, seem to be articulated one against the other, and are connected to the subgenital plate by means of a long, thin, tendonous strip, which reaches ventrad to the inner surface of the plate, where it is fastened. The forceps are about 0.29 mm. in length, spread at widest 0.29 mm., and project above the subgenital plate 0.20 mm.

FEMALE GENITALIA.—The genital segment and ovipositor of the female are of great morphological interest. The genital plates have been described by Riley as follows: "Female genital segment a little shorter than the three preceding ventral segments together; . . . upper plate a little longer than the lower one, gradually tapering toward the tip, which is straight; . . . lower plate also simple." This is in substance all that I have found in the literature to which I have had access concerning the female genitalia of this family. The genital valves or plates, being of taxonomic value, have generally been included in descriptions of species, but the ovipositor remains unmentioned, except in a few cases where it is spoken of as "ending in an acute point" (Edwards). Westwood (1839) mentions it as a "pleurivalve conical ovipositor." I have been unable to find anywhere a treatment of its structure.

I shall first treat of the two plates mentioned above, and then consider the structure of the ovipositor proper.

Of these plates, the supra-anal is of the greater interest. It is wedge-shaped, with its apex blunt and its proximal end three-sided. It averages in length 0.98 mm. and in width 0.42 mm. Its shape is well shown in *35*-4, where the ovate openings at its basal angles can be seen. These latter may be of use in attaching the plate to the abdomen. The plate is somewhat convex but not so much so as the subgenital plate. It bears on its upper surface sensory hairs, probably tactile, and is quite heavily chitinized except for a large oval space, *y*, about 0.26 mm. long surrounding the anal opening, where the plate is

almost transparent. Along the median line in this space is a slit, into the cephalic end of which the anus opens; this could be seen in a longitudinal-vertical section, where the rectum was found to run just under the dorsal surface of the posterior end of the abdomen and end at the cephalic end of this slit. About midway between this slit and the edges of the clear space are situated the curiously ornamental openings of the circumanal wax glands, outside of which are rather broken and irregular rows of short, heavy, curved, sensory hairs in pits. The dorsal aspect of this region of the plate is represented in *31*-4. This encircling band of wax glands is double; their openings are ovate to rectangular, with borders measuring 0.015 mm. in width, and are seen in the greatly magnified portion shown in *26*-5 B. Longitudinal-vertical sections showed the glands themselves. These are of large size, flask-shaped, with long necks, and are closely packed in a double row under the dorsal openings. They are illustrated in section in figure 5 A, *wg*. Their nuclei, *n*, could in most cases be made out quite plainly. These glands are of hypodermal origin, and are homologous to the circumgenital glands or spinnerets found in the Coccidæ. They are functional in the nymphal stages of most Psyllidæ, and in those forming galls the wax enters into the composition of the gall, making an impervious lining for the cavity, while it is found as a stringy, exuvial covering to some of the nongall-formers. These glands are functional in the nymph of *Pachypsylla*, but I have no evidence that they are so in the adult.

The subgenital plate is much broader and more concave than the supra-anal plate, though not so long as the latter. Its shape when flattened out is shown in *27*-8. The anterior margin is almost straight, except laterad, where it turns caudad and joins the lateral margin, forming an acute angle. The apex is blunt, as in the supra-anal plate. The approximate measurements of the plate are: Width at base, 0.73 mm.; median length, 0.63 mm.; length of lateral margin, 0.67 mm. The plate is covered with rather stiff hairs, probably tactile, more numerous at the posterior end and wanting at the anterior end; it is almost as heavily chitinized as the supra-anal plate.

Ovipositor.—The insects of the suborder Homoptera possess a well-developed ovipositor. This is well preserved and of quite complicated structure in the family Psyllidæ.

The typical structure of an ovipositor is described in the following quotation from Packard: "Morphologically, the ovipositor is composed of three pairs of unjointed styles (*rhabdites* of Lacaze-Duthiers, *gonapophyses* of Huxley), which are closely appressed to or sheathed within each other, the eggs passing out from the end of the oviduct, which lies, as Dewitz states, between the two styles of the lowest or innermost pair and under the cross-bars or at the base of the stylets mentioned; the styles or blades spreading to allow of the passage of the egg."

The structure of this organ I find to be second in interest only to the mouth parts. It is more complicated in structure than those parts in the cicada, but the homologies between the two can be worked out in part, as will be seen later. It is very similar in most points to the ovipositor in the Aleurodidæ.

Lack of material has confined my work to postembryonic studies. There has been much investigation on the segmental origin of the ovipositor parts, the researches of Wheeler and Heymons being of chief importance. Wheeler (1892), who studied orthopteran embryology, holds for the "direct continuity of the embryonic appendages with the gonapophyses," while Heymons (1899), from studies in Heteroptera and Homoptera, considers these gonapophyses as hypodermal outgrowths. However, it is not my purpose to discuss these questions, but to treat of the anatomy and homologies of the parts.

A specimen of *Pachypsylla* female, mounted in balsam after having been thoroughly boiled in caustic potash and cleared, showed, when viewed from the side, the relative position of the ovipositor as regards supra-anal and subgenital plates, and the posterior abdominal segments (*30*-4). The ovipositor is seen to be an elongate organ with dorsal and ventral outlines about parallel. It measures in length about 0.82 mm., in greatest width about 0.19 mm., and in thickness less than half that of width. The caudal extremity is acutely pointed, this portion bending dorsad, then caudad, with its apex extending caudad even with the tip of the subgenital plate, while the supra-anal plate extends caudad from this apex 0.11 mm. in the specimen described. The proximal or cephalic end of the ovipositor is composed of several sclerites of irregular form, to be described later, the ends of which project 0.16 mm. beyond a line joining the bases of the enclosing external plates to a

position about opposite and above the last spiracle, well into the dorsal portion of the last abdominal segment. Its position relative to the two plates is shown in figure 1 B, plate XXVI.

Seven longitudinal rods or valves are to be found running throughout the organ. Six of these are paired, two pairs forming the lateral edges of the ventral face of the organ, and a third pair lateral and well towards the dorsal face; the seventh and unpaired rod is dorsal and median.

Each upper and each lower valve of the two ventral pairs are very closely connected, being held together throughout their entire length by means of a tongue on the upper fitting into a groove in the lower, which may be seen in the cross section in *26*-1 A, *tg*. The tips of these valves are very sharp and finely pointed, and come together at their tips, where they are enclosed in a sheath. The cephalic ends of each ventral and inner stylet is connected with a more or less crescent-shaped sclerite (*26*-1, *blv*). The cephalic end of each ventral and outer stylet connects with a sclerite (fig. 1, *buv*) which runs dorsad and caudad. When this reaches about the dorsal face of the ovipositor it turns caudad and becomes a thin rod, *lr*, and at about the middle of the ovipositor becomes compressed laterally to form a wide, thin plate, which gradually loses its chitinization, and is lost in the fleshy tongues on each side of the ovipositor sheath (figs. 1, 2 and 3, *stp*).

Situated medially and a little dorsad of the above-mentioned rods is a rather thick, cylindrical rod bent at its cephalic end slightly dorsad, then ventrad (fig. 1, *mr*). This rod does not project quite as far cephalad as the stylets below. It is greatly swollen at its caudal extremity, with a square end, and its ventral portion is continued into a slender process, in shape much like a human femur, *procv*. This last-named process works against a ventrad-projecting outgrowth of the sheath surrounding the stylet tips, which serves to close the oviduct (fig. 1, *v*). Lying above this slender sclerite are two pairs of chitinized sclerites (figs. 1 2 and 3, *sc 1* and *sc 2*), which are connected with and probably serve to bring about lateral adjustment of the lateral tongues above mentioned. Viewed laterally, these sclerites appear as one pair (fig. 1), but when viewed from above, and pressure was applied to the dissection so as to spread the sides apart, they were seen as two distinct pairs of sclerites. Viewed in this manner, the sclerites

of the cephalic pair, *sc 1*, are pointed, with convex inner surfaces. Their tips have a connection with the lateral plates (figs. 1, 2 and 3, *pl*), the latter probably serving to spread these sclerites apart. The caudal pair, *sc 2*, reach almost to the base of the sheath surrounding the stylet tips, are rectangular in shape, with rounded ends, and with their inner surfaces corrugated, the corrugations corresponding to the striations on the surfaces of the lateral tongues of the ovipositor.

The sheath already mentioned (figs. 1, 2 and 3, *sh*) is slitted on its dorsal surface from near its cephalic edge to the apex of the ovipositor, to allow of the spreading of the stylets and the passage of the egg during oviposition. The cephalic portion of its dorsal face carries the small, valve-like, ventrad-projecting process (fig. 1, *v*).

Fig. 1, pl. *26*, shows a cross section about midway through the organ. In this the fleshy structures that were destroyed in boiling in caustic potash can be made out. The grooved and toothed valves, *uv* and *lv*, are seen fitted together, and the chitinized portion, *x*, which is grooved and forms the sides of the oviduct. Above the oviduct, and forming its roof, is the structure, *y*, whose ventral surface is covered with minute, soft, hair-like outgrowths, and whose dorsal portion is chitinized. The part marked *z* probably represents the lateral plates, *lpt*, of *30*-1, 2 and 3. The duct of the cement (?) gland is seen at *cmgd* in this figure and appears in all sections cephalad of this, and in those caudad up to the point where it turns ventrad and enters the oviduct. The entire course of this duct was best seen in longitudinal-vertical sections, but could be traced well in longitudinal-horizontal sections, where its union with the oviduct was plainly seen, and in the next succeeding sections ventrad the oviduct was laid bare. The cement (?) gland itself, a small sac, was found somewhat cephalad of the base of the ovipositor in most of my dissections. Figure 6, plate XXXI, is of a cross section near the base of the ovipositor sheath. Here the shape of the supra-anal and subgenital plates can be seen, also the position of the oviduct. The lateral tongues or sting-palpi are also represented.

I have pointed out the structure of these parts and shall now give my theories as to the homologies. The typical struc-

ture of an ovipositor as being composed of several pairs of stylets has already been mentioned.

To homologize the structure of the ovipositor of *Pachypsylla* with the structure of the typical ovipositor is more difficult than the comparison of it with that as seen in the different families of the Homoptera. I find that it is more specialized than a typical ovipositor such as found in the Orthoptera, though it is possible to show the homologies; but since it resembles more closely that found among the Hymenoptera—where it is specialized to form a sting—these homologies can be traced through the latter. Taking the sting of the honeybee as a type of the hymenopterous ovipositor, since this has been so carefully worked out by Cheshire and others, it can be seen that the lower valves of *Pachypsylla* (*30*-1 and 3, *lv*) correspond to the lower and outer pair of *darts* in the honeybee. The upper valves of *Pachypsylla* correspond to the inner pair in the bee, where they are fused into one piece to form the *sheath*. It should be noted here that the *sheath* does not correspond to that part of the ovipositor of *Pachypsylla* which I have designated by that name. In the honeybee there are two fleshy processes, one on each side of the sting, which are thought to represent the upper pair of stylets and are called the "sting-palpi" or "feelers." These are evidently the same as the lateral tongues found in *Pachypsylla*.

The homologies up to this point are comparatively clear, but as to the remainder of the parts I can only theorize, as their structure is complicated and there are present more pieces than in the typical organ. The lateral tongues evidently are the "sting-palpi" and together with the *lateral rods* and *lateral plates* form the upper pair of stylets; but this explanation does not account for the *median rod* with its processes and appendages. There may be three possible explanations for these structures:

1. This *median rod* might be regarded as a fusion of the dorsal pair of stylets, and the *rods* and *lateral plates* only as tendons causing the spreading of the *sc 1* and *sc 2* and consequently the *sting-palpi*.

2. The *rods* and *lateral plates* might be considered as composing the dorsal pair of stylets and the *median rod* as an accessory structure which, moving backward and forward, would spread and close the *sting-palpi*, for these latter are

evidently in as intimate a relation to the *median rod* as the *lateral rods*. Hence, there is possible a third theory:

3. According to Lacaze-Duthier's view, there are "two pieces forming the outer pair of rhabdites" (after Packard), as seen in the figure illustrating his conception of the ideal ovipositor. In *Pachypsylla, one* of these "pieces" might be the *rod* and the *lateral plate* which connects basally with the lever supporting the base of the upper valve, *buv,* and distally with the tongues or *sting-palpi.* The *median rod,* then, might represent the second of the "pieces," its two parts fused into one. Thus *rods* and *lateral plates,* together with the *sting-palpi,* would form one portion of the upper pair of valves while the *median rods* represent the other paired portion, fused. The sheath may also belong to the second piece of the upper valves, as do the two pairs of small sclerites, *sc 1* and *sc 2* (*30*-2). The levers supporting the bases of the lower valves, *blv,* find their homologues in similar structures in the honeybee, termed there simply "levers," which are the point of attachment of muscles moving the sting. They have a similar function here, serving to spread the styles.

The ovipositor of the cicada has been described and figured by Marlatt (1895). A rather superficial study of this form from my own dissections has rendered the following facts and hypotheses as to the homologies between this form and *Pachypsylla:* There are found two pairs of blades, the dorsal pair grown together, and the two pairs sliding on one another by means of tongues and grooves much as I have shown to be the case with *Pachypsylla.* The tips of the ventral pair of blades are serrated for cutting purposes. These two pairs of blades evidently correspond to the upper and lower valves or styles of *Pachypsylla,* though in the latter there is no need for their tips to be modified for cutting, as the eggs are not deposited within plant tissue. In *Cicada* there is a very large sheath surrounding the entire ovipositor, except for a slit beneath, which probably corresponds to the supra-anal plate. Marlatt says, "The ovipositor is protected and covered when at rest by two valves, which form a sort of sheath or scabbard." These second valves mentioned by Marlatt, which are dorsad of the blades, proximad are broad, and made up of chitinized and more or less membranous portions, and distad are composed of two distinct and distally separable scabbards

covering the tips of the blades dorsally and laterally, and open entad and ventrad. The basal portion is evidently a complex made up of parts corresponding perhaps to the *median rod, lateral rods* and *lateral plates,* with their processes, appendages, etc., of *Pachypsylla,* while the two scabbards may be homologous to the *sheath.* The *sting-palpi* are not represented in *Cicada.*

The ovipositor of one species of Aleurodidæ which I have examined showed features most similar to those of *Pachypsylla* of any other insect, the parts being much more easily compared with those of this insect. The upper and lower pairs of converging blades or styles were found, together with a sheath enclosing their apices, while their bases bore irregular supports as in *Pachypsylla. Sting-palpi* and *sc 1* and *sc 2* were also present.

GENERAL SUMMARY.

1. The head is made up of the typical sclerites.

2. The mouth parts conform in general to those of other homopterous forms, such as those of the Cicadidæ, Aphididæ, Aleurodidæ, and most closely to those of the Aleurodidæ, differing most from those of the Coccidæ.

3. The mesoterga and metaterga show three sclerites only. The pleural sclerites are much folded, with their sutures almost obsolete. The internal skeleton of mesothorax and metathorax is large and heavy, making the segments very rigid.

4. The metathoracic legs are greatly specialized for jumping, the tibiæ being provided with heavy spines on their distal ends, and the coxa, epimeron, meracanthus, a part of the sternum, and an accessory sclerite compose a single complex of sclerites which encases powerful jumping muscles.

5. A study of the tracheation of nymphal wing pads and wings of recently emerged adults has shown that there are present in the adult wing the following veins: one costa; one subcosta; one radius; one two-branched media; one two-branched cubitus; one anal vein; and a vein occupying the anal fold, seen only in nymphal wings, being represented only as a fold in the adult wing. Previous writers have not indicated the media and cubitus as separate veins, but I have shown them to be represented by separate parallel tracheæ in the wing pads. The subcosta of the hind wing, previously unfigured, was found in recently emerged specimens. A sport vein, pos-

sibly representing the second anal vein, was found in one specimen.

6. The color pattern was found to consist of polygonal or irregular groups of pigmented, disklike outgrowths of the cuticula. The manner of producing the pattern is various.

7. The male genitalia were found to consist of supra-anal plate, subgenital plate, couplatory organ and forceps.

8. The female genitalia consist of supra-anal plate (ornamented with a double row of wax glands, flask-shaped in longitudinal section), subgenital plate and ovipositor. The ovipositor was found to be homologous in many points to a hymenopterous ovipositor as seen in the honeybee (a sting). Comparison with other homopterous forms showed it to be homologous in most points with that of the cicada, but almost identical to that of the Aleurodidæ, showing, with the buccal appendages, the close structural relationship of the Psyllidæ to that family.

TECHNIQUE.

My studies have been based upon dissections and serial sections.

Dissections were made in three ways: (1) A dissecting stand fitted with an 0.8-inch lens was used in some cases; (2) some of my work was done under a compound microscope (one-inch eye-piece and one-inch objective) on the lower end of whose draw-tube was placed a three-inch objective, thus producing an erect image. This combination was useful but its disadvantage was that the eye was too far from the specimen being dissected on the microscope stage; (3) the greater part of my dissecting, however, was done under a "Pfeiffer's Erect-vision Dissecting Microscope" using objectives three inch, one inch and two-thirds inch. This was found to be the most convenient, especially in the more delicate dissections, such as of mouth parts and genitalia. By the use of very fine, sharp-pointed needles, these minute organs could be torn apart with ease.

Most of my material was boiled for a short time in caustic potash, and then treated with alcohol and xylol previous to dissections, no fresh specimens being available at the time when this work was done. Xylol was of great use in clearing the parts, but at the same time it rendered them brittle and easily broken.

Dissections were made under water, alcohol, xylol and glyc-

erine. Xylol was a very clear medium, having the advantage that uncleared specimens could be dissected in it, soon becoming clear, but it evaporated very quickly, and, lacking viscosity, allowed too much movement of the parts being dissected. Glycerine was found to possess the necessary viscosity and was the most satisfactory medium in most cases.

The nymphal wing pads were removed with fine scissors, holding the nymph the while between the finger-tips; the pads were mounted in dilute glycerine after being kept in formalin for about twenty-four hours.

Serial sections were made through the mouth parts and genitalia, and cross, longitudinal-horizontal and longitudinal-vertical sections through the entire insect.

Killing and Fixing.—Live insects were killed by plunging into a boiling saturated solution of corrosive sublimate containing about one per cent of acetic acid, and after being punctured with a piece of glass drawn out into a fine point were left in the solution to fix for twenty-four hours.

Dehydrating and Clearing.—The insects were placed in small vials with ends covered with cheesecloth, and run through alcohols of percentages 70, 85 and 95, twenty-four hours in each. They were removed to absolute alcohol for about twelve hours and then run into xylol for about twelve hours.

Infiltration and Embedding.—Leaving the specimens still in the vials they were infiltrated in a paraffin oven with paraffin of melting-point 50-55° C. for forty-eight hours. They were then embedded in paraffin in small paper dishes, being oriented properly as the paraffin hardened when the dish was floated on cold water.

Sections.—Serial sections 10-20 microns thick were cut on a sliding microtome. The ribbons were floated onto Mayer's albumen fixative on a clean slide, the excess of fixative drained off with filter paper, and the slide dried on top of the paraffin oven for twelve or more hours. The slide was then left for ten to fifteen minutes in xylol to remove the paraffin, when it was run through the following grades of alcohol, five to ten minutes in each: 95 per cent, 85 per cent, 70 per cent, 50 per cent, 35 per cent, 25 per cent, and then into water, after which the sections were stained in Mayer's Carmalum, ten to fifteen minutes, washed in water and run back through the alcohols, beginning with twenty-five per cent, into absolute alcohol, five

to ten minutes in each. They were then cleared in xylol and mounted in balsam.

In running the sections into and out of the stain (aqueous) the lower grades of alcohol, 25 per cent and 35 per cent, and then water, were necessary, as without their use the transfer into the stain from 70 per cent alcohol was found to be too sudden, causing currents which tore the sections loose from the slide. Any dirt or grease on the slides made this more certain. However, cleaning the latter in 95 per cent alcohol containing a few drops of hydrochloric acid obviated this.

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